Water Consumption

What is the major ingredient in brewing? - Water.

How much is used?

$$\frac{6 \text{ volumes water}}{\text{Volume of beer}} \quad [=] \quad \text{liters | gallons | barrels | etc}$$

6 - Broken down

Brewing Water - 2.7 volumes
Process Water - 2.1 volumes
General purpose - 1.0 volumes
Service Water - 0.2 volumes

Brewing water - water that makes the beer, comes in contact with brewing ingredients.

- mashing | lautering water
- Post boil adjustment water
- Evaporation

Spent grains -

20% grain
80% Water

Example

100 lbs 2-row CG 76.5 %. Assuming 100 % BHE

= 76.5 lbs extracted

23.5 lbs spent grain

$$\frac{23.5}{0.2} = 117.5 \text{ lbs (grain + water)}$$

$$(\times 0.8) = \boxed{94 \text{ lbs water}}$$

Gravity Adjustments

$C_1 V_1 = C_2 V_2$

C = GU or °P / °B

V = volume

Gravity Units - GU

GU = (SG - 1)(1000)

ex)

1.060 SG = GU = 60

10 gallons

To adjust a gravity

Have 100 barrels of 1.058 unfermented wort, what volume of water must you add to get an SG of 1.048?

$\frac{(100 \text{ Barrels})(58 \text{ GU})}{(48 \text{ GU})}$ = 120.8 Barrels Total

120.8 - 100 = 20.8 Barrels added

or

$\frac{(100 \text{ Barrels})(14.5\ °P)}{12\ °P}$ = 120.8 Barrels Total = 20.8 Barrels

Other uses Brewing water:

yeast washing / dilution - adding water to yeast

Evaporation Rates 4-5 % volume / hr

* Different Schemes to minimize evaporation losses

Process Water

- Water used Washing/Sterilizing different components
  - mixing detergents
  - heat exchangers i.e. refrigerators, heating, etc.

General purpose water

- Drinking, "office use"

Service Water

- Boiler Feed

Water Chemistry

Ca^{2+} Mg^{2+} - Lower pH
HCO_3 CO_3 - Raise pH

- Mash pH

Water Hardness - total positively Charged (Ca) (Mg) Cations
Water Alkalinity - total (HCO_3) (CO_3) anions
Bicarbonate Carbonate

Salt forms

* H_2O hydration shell

Gypsum - Calcium Sulfate - $CaSO_4 \cdot (2H_2O)$ - Ca = 23% SO_4 = 56%
Calcium Chloride - $CaCl_2 \cdot (2H_2O)$ - Ca = 27% Cl_2 = 48%
Epsom Salts - Magnesium Sulfate - $MgSO_4 \cdot (7H_2O)$ - Mg = 10% SO_4 = 39%
Chalk - Calcium carbonate - $CaCO_3$ - Ca = 40% CO_3 = 60%
Table Salt - Sodium Chloride - NaCl - Na = 40% Cl = 60%

Acceptable levels

Cl^{-2} - 50-100 ppm - Palate fullness
(Sg > 1.050 = 350 ppm)
Ca^{+2} - 5-200 ppm - Mash Chemistry
Na^{+} - 2-100 ppm - Salty
SO_4^{-2} - < 500 ppm - Dry, Sharp

Mg^{+2} - 0-70 ppm - Bitterness

ex1 Desire 200 ppm Ca in water containing 50 ppm

Volume = 100 Liters

Ca Required: 200 - 50 = 150 ppm = $\frac{150 \text{ mg}}{\text{liter}}$ $\left(1 \text{ ppm} = \frac{1 \text{ mg}}{L}\right)$

Total Ca Required: $\frac{150 \text{ mg}}{L} \cdot 100 L = 15000 \text{ mg}$

Total Gypsum Required: $CaSO_4$ = 23% Ca → $\frac{15{,}000 \text{ mg}}{0.23}$ = **65,217 mg gypsum**

Residual Alkalinity Mash Target pH: 5.2 - 5.8

- Limits phenol extraction from husk and color formation
- Improves protein coagulation
- Improves mash bed filterability

Water hardness - total (See previous definitions) - important in mash chemistry

Water alkalinity - - Buffers acidification

equivalent units

	M.W	Valence	equil wt	PPM per °dH
Ca	40 g/mol	+2	20	7.14
Mg	24.3	+2	12.2	4.36
CO_3	60	-2	30	10.7
HCO_3	61	-1	61	21.8
$CaCO_3$	100		50	17.85

PPM per dH = $\frac{\text{eq. wt}}{2.8}$

equivalence - common denominator

$1°dH = \frac{10 \text{ mg}}{L}$ CaO

example - Calculating equivalent wt

$CaCO_3$

100g

Ca^{+2} — 40 g/mol

CO_3^{-2} — 60 g/mol

$$eq.\ wt = \frac{40}{2} + \frac{60}{2} = 50$$

Water Reports

ex1

	PPM
Calcium -	34
Magnesium -	4
($CaCO_3$) Alkalinity -	54
($CaCO_3$) Hardness -	102

Calcium and Magnesium Contribute to hardness.

↓

$$\frac{34\ PPM\ Ca}{20\ eq\ wt\ Ca} = 1.70 \text{ milliequivalents}$$

$$\frac{4\ PPM\ Mg}{12.2\ eq\ wt\ Mg} = 0.33 \text{ milli equivalents}$$

* milliequivalents are the common denomenator.

→ Can express in terms of $CaCO_3$, Ca, Mg, HCO_3, etc.

1.70 + 0.33 = 2.03 milli equivalents

* Expressed as $CaCO_3$ → 2.03 · 50(eq wt $CaCO_3$) = 102 ppm $CaCO_3$

↓

*** This is how 34 PPM Ca and 4 ppm Mg are equal to 102 ppm hardness.

Paul Kolbach →

3.5 equivalents Ca and 7.0 equivalents off set 1 equivalent of $CaCO_3$ in terms of pH changes

Residual Alkalinity

$$RA\ (mEq) = \frac{PPM\ CaCO_3}{eq\ wt\ CaCO_3} - \left[\frac{\left(\frac{PPM\ Ca}{eq\ wt\ Ca}\right)}{3.5} + \frac{\left(\frac{PPM\ Mg}{eq\ wt\ Mg}\right)}{7} \right]$$

Convert mEq to PPM $CaCO_3$ by multiplying by eq. wt. $CaCO_3$ (50).

Predicting Mash pH

$$\text{Mash pH} = 5.8 + (0.03)(RA)$$

5.8 ↓ pH of mash if it were made with DI water

* RA = needs to be in terms of °dH
↓
Refer to Chart from before.

* 1 °dH causes a pH change of 0.03

Example

If mash is performed with water from previous water report:

what pH would it have?

Using residual Alkalinity equation;

$$RA\ (mEq) = \frac{54\ ppm\ CaCO_3}{50\ eq\ wt\ CaCO_3} - \left[\frac{\left(\frac{34\ ppm\ Ca}{20\ eq\ wt\ Ca}\right)}{3.5} + \frac{\left(\frac{4\ ppm\ Mg}{12.2\ eq\ wt\ Mg}\right)}{7.0} \right]$$

$$RA = 1.08 - (0.486 + 0.047)$$

$$= 0.55\ mEq$$

$$0.55\ mEq \cdot 50\ eq\ wt\ CaCO_3 = 27.5\ ppm\ CaCO_3$$

Want to convert ppm $CaCO_3$ to °dH:

From $\frac{eq\ wt\ CaCO_3}{2.8} \rightarrow \frac{50}{2.8} = 17.85\ \frac{ppm\ CaCO_3}{°dH}$

$$\frac{27.5}{17.85} = 1.54\ °dH$$

$$pH = 5.8 + (0.03)(1.54)$$

$$= 5.846 \rightarrow \text{too high}$$

* Would add $CaCl_2$ or $CaSO_4$ or $MgSO_4$ to lower pH

Manipulating Mash pH with other methods

* Can add acids → 100% Lactic acid — 58 grams — to reduce pH by 0.1
  - 37% Hydrochloric — 63 grams — to reduce pH by 0.1
  - 98% Sulfuric — 32 grams — to reduce pH by 0.1
  - ↓ Per 100 kg of grain

Using acidulated Malt

Acidulated malt in Distilled Water has pH → 3.5

↳ Maillard Reactions : Acidic melanoidins

Weighted grist %

	pH	%		
2-Row	5.8	95	=	5.510
Acidulated	3.5	5	=	0.175
			+	**5.685 pH**

↓

This value would be placed into Predicting Mash pH equation if further salt additions are required.